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Team 4: NATO MSG-088 Data Farming In Support Of NATO Case Study on Force Protection

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INTRODUCTION

In 2010, the NATO Modeling and Simulation Task Group "Data Farming in Support of NATO" (MSG-088) has been established with the goal of assessing the data farming capabilities that NATO, PfP, and Contact Countries, schools, and agencies have as well as to find out in which way these capabilities can contribute to the development of improved decision support to NATO forces.

As part of the "Program of Work" of MSG-088, proof-of-concept explorations regarding questions and models of interest to NATO nations are to be conducted, with the objective of illustrating the power of data farming for decision support. In order to realize this MSG-088 objective, the task group has planned to set up two case studies. One of those is taking place in the area of "Humanitarian Assistance and Disaster Relief (HA/DR)", whereas the second case study works on the topic "Force Protection". For those two case studies, two NATO working groups have been established, both contributing to IDFW.

During IDFW23, Team 4 represented the MSG-088 case study team "Force protection".

The proposed scenario topic for the "Force Protection" study deals with the effective protection of a combat outpost (COP), possibly with the support of joint fire assets, in an Afghan mission setting against strong and coordinated insurgent forces.

The entire "Force Protection" scenario has been defined at the previous NMSG-088 meeting 2 / IDFW 22 workshop including the questions we want to answer using data farming, the measures of effectiveness and the list of all input parameters that should examined. In preparation for the NMSG-088 meeting 4 / IDFW 23, the scenario was implemented using the German agent based sensor and effector model PAXSEM and was reviewed at the NMSG-088 meeting 3 in Istanbul, Turkey in July 2011. Afterwards, data farming experiments with the created scenario as well as with the defined DoE using a "Nearly Balanced Nearly Orthogonal Mixed Design" was conducted with PAXSEM in order to perform statistical analysis with the simulation results at this workshop.

The Overall Question

The overall question that has been agreed upon to investigate in this context is the following:

"Which tactics / equipment is most robust against different kinds of threats?"

To answer that question, the following three subquestions have been defined:

1. Is there a COP configuration that performs consistently well?
2. What is the most dangerous threat and how does the robust COP work for that threat?
3. Under which circumstances can joint fire support improve the survivability of the COP? (Find out

necessary requirements e.g. early availability of joint fire)

The initially stated general question also contains the investigation of the chosen solution's robustness. To also incorporate this aspect, the approach agreed upon was to run the different COP setups or strategies, that are to be tested according to the questions above, against different kinds of insurgent threats and from these results compute the average performance of a specific COP setup.

Scenario Description

The general scenario setup can be described as follows:

A COP is set up next to an Afghan village. It is equipped with various sensor and weapon systems, which help to identify enemies and to protect itself. The sensors as well as the effectors are placed inside and outside of the COP.

Sensors inside the COP may be positioned e.g. on set-up watchtowers or placed on vehicles, whereas an external sensor could be positioned at a observation point (OP) on a nearby hill to get a better overview over the area. Additionally, the COP has access to UAVs, which can be used to scan the area, and also sends out patrols, which provide the possibility to detect enemies before they attack the COP.

In terms of effectors, the COP on the one hand has access to weapon systems stationed inside the COP, like the soldiers' rifles, mortars and effectors placed on the vehicles stationed inside the COP. From outside the COP, joint fire support in form of helicopters, fixed wing aircrafts or artillery can be called in, once a suitable target has been identified.

The red forces on the other hand apply two kinds of tactics to attack the COP. They either attack in the form of homogenous long distance attacks with the help of mortars or sniper rifles, or they approach the COP in the form of a force-on-force attack, seeking direct confrontation.

The course of action in this scenario is that the soldiers inside the COP try to have a good overview over the area around them, and try to reconnoiter enemies either through patrols, UAVs or stationary sensors placed in and around the COP. The insurgents on the other hand try to attack the COP with different tactics. As soon as the attackers have been reconnoitered by the soldiers, countermeasures can be applied, like sending out a Quick Reaction Team (QRT), defending themselves from inside the COP with help of rifles, mortars or other effectors, or by calling in joint fire support.

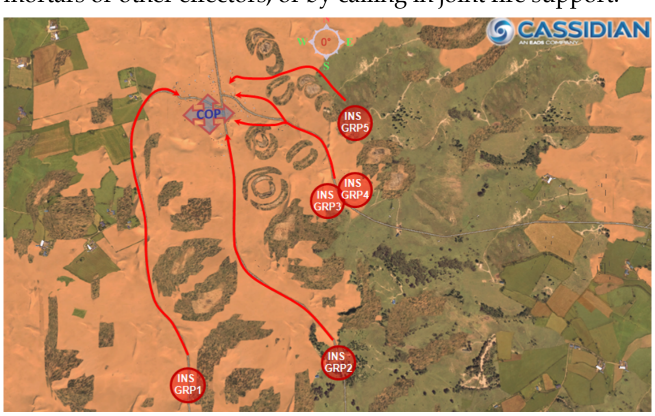


Figure 1: Scenario: force-on-force attack on COP

Measures of Effectiveness

The following MOEs (Measures of Effectiveness) have been identified as being suitable to actually identify the performance of the course of action in terms of the formerly formulated overall question:

How to define successful protection of COP?

- No blue casualties
  ➔ **MOE:** percentage of blue losses
- No insurgents within small arms fire distance
  ➔ **MOE:** count the number of INS within given environment
- How long can the COP hold out until reinforcement / joint fire support arrives?
  ➔ **MOE:** count number of blue casualties within certain period of time

  ➔ **MOE:** ammunition spent

How to measure robustness?

- Steady success against varying strength / capabilities / tactics of INS
- Specify a target function considering weighed MOEs

General Scenario Assumptions

In defining the rough outline of the scenario, a few assumptions had to be made regarding the scenario in order to keep the investigation focused on the formerly defined questions. These assumptions include:

- The COP in question is generally meant to be a small, platoon-size COP, as attacks on large, heavily fortified COPs are highly unlikely.
- Though generally regarded as an important factor in such missions, no explicit modeling of communication between the different entities of the blue forces will be done.
- Intelligence processes won't be modeled, but the presence of intelligence results will be considered in the initial scenario setup.
- In the first step, no civilians will be modeled, as the involvement of these would make the scenario too complicated.
- The COP will be set up in the terrain next to a village. This implies that the COP can not attack the insurgents as soon as they retreat to the village (prevention of collateral damage).
- The COP's objectives have been defined as "Observe the surrounding" and "Show presence". None of the more complex tasks that are usually assigned to COPs, like setting up road checkpoints or building a relationship with the civilian population, are depicted in the scenario.

Defining Input Parameters

For the described scenario, various input parameters have been defined that are deemed likely to have an influence on the course of the scenario and the outcome in terms of the formerly defined MOEs.

On the blue side, the parameters to vary can be summarized as follows:

- The number of sensors, effectors and vehicles at the COP's disposal
- The number of patrols that are being sent out by the COP
- Number, availability, latency and effector parameters of helicopters, fixed wings and artillery that can be used as joint fire support
- The number, type and tactics of UAVs working for the COP
- The number and type of stationary sensors inside and outside the COP
- The blue force's tactics in case they are under attack
- The proficiency of the soldiers inside the COP
- Availability of intelligence reports

On the red side, the parameters to vary are the following:

- Change between long distance and force-on-force attacks
- In case of long distance attacks, the number of attackers and their likelihood after firing to stay in their position or to change it
- In case of force-on-force attacks, the constellation of the attacking force, whether it is more small groups attacking or one large group of insurgents
- Effectors used by the attackers
- The insurgents' strength and proficiency

Due to the mixture and combination of the chosen input parameters, of which some are numerical and others categorical, the "Nearly Balanced Nearly Orthogonal Mixed Design" was chosen, which was developed at the NPS. With this design it will be possible to reduce the initially calculated number of $9 * 10^{27}$ design points based on the 26 decision and 15 noise factors to a number of 5610 design points.

Results

The working team built a major analysis plan consisting of the following steps:

1. Check the ranges of simulation output / MOEs
2. Check distribution of input parameters
3. Check correlations using multivariate plots for numerical factors / contingency tables for categorical factors to check correlations and the validity of design
4. Descriptive statistics to validate output data
5. Generate loss functions
6. Check partition tree to find out most important factors (including all factors)
7. Do regression analysis through stepwise linear regression (choosing leave labels of partition tree) taking into account continuous factors
8. Determine threshold between important / unimportant factors
9. How to set factors to achieve lowest level of blue losses

All these steps have been done using SAS JMP. The interesting details are described in the following sections.

Robust Analysis

To answer the first subquestion

"Is there a COP configuration that performs consistently well?"

a robust analysis was conducted using the MOE "BlueLoss" . The goal of the robust analysis was to look for a COP configuration that simultaneously yields good average performance and low variability through all kind of threats.

The following two alternatives to perform the robust analysis on the MOE "BlueLoss" have been considered:

The first alternative uses a loss function that captures the average performance and volatility, looking for consistent good performance. The loss function should have a target value that represents a desirable and achievable value e.g. 5% blue losses. Therefore the quadratic loss function

$$f_{loss}(\text{BluesLoss}) = (\text{BlueLoss} - 0.05)^2$$

was used as the target value for a regression analysis, to find the most influencing factors to minimize the loss function.

The second alternative is to compute the mean and standard deviation for the MOE "BlueLoss" grouped by all decision factors. Then two separate regressions are performed to find the most influencing factors: one regression for the mean and one regression for the standard deviation of the blue losses as a response factor considering all decision factors.

Both alternatives led to similar results. Using the given loss function for the blue losses and performing a regression tree (see figure 2), the following decision factors were identified to be most important:

The ammunition supply, the soldier's proficiency level, the number of medium machine guns and guided rockets need to be maximized.

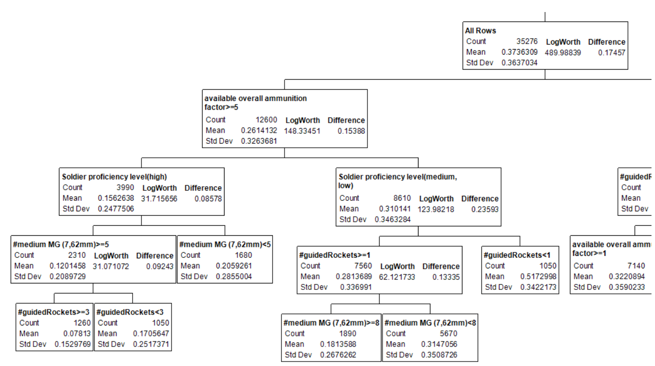


Figure 2: Part of the regression tree on the loss function for blue losses

An additional regression analysis did not enhance the insights. But adding the number of blue forces to the model improved the robust results which shows, that the overall force size is important to survivability of the COP.

Robust COP Configuration for Most Dangerous Threat

To answer the second subquestion

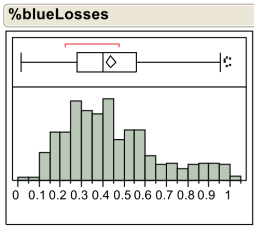
"What is the most dangerous threat and how does the robust COP work for that threat?"

the most dangerous threat has to be identified first.

Therefore a partition tree was build using the previous loss function (target value 5%) but now considering all noise factors as input factors. This showed that certain insurgent configurations (e.g. the long distance attack with many indirect fire weapons) result in the highest blue losses (mean of 88% of blue losses).

The intersection of the subset of most dangerous insurgent configuration with the subset of the most robust COP configuration shows the requested COP performance on the most dangerous threat. Looking at the distribution of blue losses showed, that the most robust COP does substantially reduce the blue losses (mean of 44% of blue losses). See figure 3.

%blueLosses



Quantiles

100.0%	maximum	1
99.5%		1
97.5%		0.95455
90.0%		0.79493
75.0%	quartile	0.55556
50.0%	median	0.4
25.0%	quartile	0.28098
10.0%		0.18182
2.5%		0.13158
0.5%		0.08405
0.0%	minimum	0.01538

Moments

Mean	0.4387664
Std Dev	0.2170466
Std Err Mean	0.0111637
Upper 95% Mean	0.4607173
Lower 95% Mean	0.4168156
N	378

Figure 3: Distribution of blue losses of the most robust COP against the most dangerous threat

Scenario improvements

Trying to answer the third subquestion about the impact of fire support assets showed that the request for fire support in the scenario was always requested way too late so that there was almost no impact on the simulation outcome. Because this doesn't reflect the reality some minor scenario changes have been defined, so that the fire support may be requested earlier:

- The UAV and sensor towers may detect any suspicious persons or vehicles. At this point, fire support assets may already be requested for preparation
- To be able to identify the insurgents and immediately call for fire support, a quick reaction team (QRT) is send out of the COP after the detection to perform the identification

These scenario modifications shall be implemented until the next IDFW24 / NMSG-088 Meeting 6 in Monterey in March 2012, to continue the analysis using the new result data of the updated farming experiment.

SUMMARY AND FURTHER STEPS

Great progress could be achieved during this week of collaborative work and important steps towards conducting the case study "Force Protection" could be made. Due to all the valuable inputs from experts in the military, DoE and M&S fields, it has been possible to conduct a first analysis on the data farming results to answer the first two of the three subquestions of this case study. We are on a good way to show how the data farming methodology is capable to be used to answer analysis questions in the military area.

Currently, the further plans for the "Force Protection" case study is to implement the necessary scenario modifications into the model PAXSEM and to conduct the data farming experiments with the modified scenario as well as with the adjusted DoE. So the results of these experiments will be presented for analysis at next IDFW24 / NMSG-088 Meeting 6 in Monterey in March 2012.

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[1] Data Farming in Support of NATO, RTG, March 2010

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[4] IDFW 23 Team Abstracts, 2011, SEED Center for Data Farming